THE POLAR DIFFERENTIATION OF VOLVOX, AND THE SPECIALIZATION OF POSSIBLE ANTERIOR SENSE-ORGANS.

BY JOHN A. RYDER.

IN a recent communication upon this subject which the writer made to the Academy of Natural Sciences of Philadelphia, the fact was pointed out that in *Volvox minor* there are very distinctly differentiated anterior and posterior poles or hemispheres. The anterior or empty pole is so named here because it is the one which is always directed forwards when the animal is in motion. The posterior pole is so named because it is always in a posterior position when the organism is moving freely and normally, and it is further distinguished from the anterior in that it is in this hemisphere, in *V. minor* at least, in which the germs are produced which give rise to young Volvoces. Roughly speaking the nearly spherical cænobium or colony of Volvox may be divided into an anterior and a posterior hemisphere. Through the centres of these hemispheres there passes an imaginary axis around which the colony rotates in either a sinistral or dextral direction, but progressive locomotion is always in the direction of the anterior empty pole of the cænobium. This differentiation of the poles of the colonies of Volvox appears to have been known to Ehrenberg, who figures them but makes no farther mention of the fact. Hicks is reported in the *Midland Naturalist*, 1880, to have observed that the young leave the parent cænobium by breaking through the wall of the hinder or spore-bearing hemisphere, a fact which I can confirm.

While these facts have been partially recorded by previous observers, there is another group of facts which I have noticed which are far more important and remarkable and serve to establish beyond question the polar differentiation of Volvox, and also raise the suspicion that this animal or plant, whichever it is, is endowed with a very primitive sensory apparatus which is developed to an importance anteriorly, eight or ten times as great as at the posterior pole. It is well known that

each one of the biflagellate cells of Volvox contain superficially embedded a reddish lenticular refringent body known since Ehrenberg's time as "eyes" or "eye spots." One of these "eye spots" lies not very far from the base of one of the flagella in each cell, and produces a slight rounded projection of the thin layer of clear protoplasm immediately overlying and surrounding it. In optic section these reddish bodies are seen to be lenticular or nearly so, the outer face being less convex than the inner. This is best seen in the "eye-spots" of the anterior pole. These "eye-spots" strange to say, bear a constant and definite relation to both the imaginary axis around which the colony revolves and the flagella of its cells. They are placed not quite on the extreme outer periphery of the cells as reckoned from the centre of the globular colony, but nearly so. The anterior ones at the anterior pole consequently look forward, while the others of the rest of the cells look in all other directions, the hindmost ones looking directly backward.

Now comes the most singular and interesting fact which I have observed, viz: *that the "eye-spots" of the cells of the anterior pole are eight to ten times as large as those of the hinder pole.* The passage from the large "eye-spots" of the anterior pole to the smaller ones of the posterior pole is very gradual, as can be readily observed with a moderately high power. These "eye-spots" diminish so much in size on passing to the cells of the posterior pole as to be finally visible only as a minute refringent reddish globule pushing out the protoplasm of the cell slightly in the same way as the larger anterior "eye-spots" push out the superficial plasma of the cells of the anterior pole.

It is therefore plain that if these organs are visual or sensitive to light or any other natural agent, they are best developed in just the position in which they are of the most service to the organism, viz., at its anterior pole. These facts raise the query whether Ehrenberg was not after all justified in regarding the reddish spot in each cell of the colony as *eyes.* While these eyes are obvious to any observer it is remarkable that no one has hitherto called attention to their very unequal development at

the anterior and posterior poles of Volvox. It is equally remarkable that none of the extant figures of Volvox correctly represent the definite relation of position of the "eye-spots" to the axis of rotation of the whole cænobium or colony and the flagella of the cells.

The facts which are here noted in regard to Volvox serve rather to strengthen the claims of zoologists to this singular organism, which is actually found to combine features of the vegetable and animal world in its physiological activities. While its respiration, chlorophyl, and modes of reproduction seem to affiliate it with the plant kingdom, the obvious differentiation of a system of anterior organs, which refuse any other identification than that of sensiferous structures give it claims upon the animal kingdom. If we look upon Volvox as a form which has permanently not passed beyond the ideal blastula stage and which lies near the point of divergence of Metaphyta from the Metazoa we shall probably assign it to nearly its true position. It has many interesting features, one of which is its blastula-like form; its cells embedded in cellulose and united by protoplasmic bonds into a sort of syncytium; its differentiation of a directive anterior empty pole apparently provided with a more specialized sensory apparatus, as pointed out above, and of a posterior reproductive pole or hemisphere, in the cells of which the supposed sensory apparatus is so reduced in importance as to have been nearly suppressed. Carrying our reflections farther, we may be permitted to suppose that conditions of organization may and do exist, as evidenced in Volvox as here described, in which structures and functions may be manifested, which we must regard as sensiferous, yet in so low and generalized a form in a blastula-like type, that we find the organs developed in every cell, the only evidence of differentiation or specialization obtainable being that which occurs at that pole of the blastula which is habitually brought into the most important or dangerous relation to the environment. The end result being that a type comparable to the hollow blastula has the sensiferous apparatuses of the cells at its constant anterior pole better developed than in

those around its equator and still better than in those at its constant posterior pole. The diffusion or extension of the primordial visual apparatus of the protozoan grade such as is seen in Euglena, is a result merely, in Volvox, of the permanent attainment of the colonial grade of development which has ended in a sort of blastula-like form, each cell of which is provided with a sense organ. In other words we have in Volvox a blastula-like type with a sensory apparatus apparently developed at its anterior pole, while at its posterior pole this sensory apparatus is so little developed as to be nearly absent, possibly owing to disuse. The degree of development of this supposed sensiferous apparatus at opposite poles in Volvox stands in an obvious relation to the respective importance of such a contrivance at those poles in relation to the welfare of the organism. It is probable that, if what I have here described is really a visual or other sensory apparatus, it is the most primitive and unspecialized compound sensiferous organ yet detected in the living world. At any rate it is probably to be regarded as a compound organ in the same sense that the retina and ommatidia of other and higher forms are to be regarded as compound organs in that they are cellular aggregates. The further study of these remarkable structures and relations in Volvox is desirable, and as the organism is accessible to many students it is to be hoped that such study may not be long delayed, and that not only a more careful study of the minute structure of the "eye-spots" may be carried out, but also that figures will be produced which will give adequate prominence to the most important of the facts which I have here attempted to put upon record.

THE DEVELOPMENT OF THE THEORIES OF CRYSTAL STRUCTURE.[1]

IN 1822, the Abbé Haüy[2] declared that since all crystals of the same substance, whatever their external form, may be

[1] Abstracted by. W. S. Bayley from an article by H. A. Miers in *Nature* of January 17, 1889.

[2] "Traité de Cristallographie." (Paris, 1822.)